ATTACHMENT C

OCCUPATIONAL EXPOSURE ASSESSMENT FOR NPB

1. INTRODUCTION

N-propyl bromide (NPB) is used in various solvent, aerosol, and adhesive formulations as an alternative to ozone-depleting substances (ODS) such as methyl chloroform. However, in animal studies, NPB has been shown to exhibit toxicity to the liver and reproductive system following inhalation exposure. To date, the potential for worker exposure to NPB across the range of facilities where it can be used has not been adequately assessed. This document attempts to provide a brief assessment of exposures in the adhesive end use. Occupational exposure data for other end uses is summarized in section 6 of Attachment A.

In general, NPB usage in adhesive applications is emissive. Significant occupational exposure can occur when a spray gun is used to aerosolize the adhesive. Exposure levels depend on multiple factors including the ventilation in the room, the size of the room, the amount of NPB being used, and proximity to the spray gun. The aerosol mist is present in the work area throughout the production process. Since workers typically spend 8 hours per day applying adhesive, this assessment focuses on the long-term occupational exposure to NPB as a result of inhalation. Potential impacts from higher exposure levels, such as those that could occur from an accident or spill, are not assessed in this study.

Section 2 of this report presents the exposure setting of NPB in the workplace; Section 3 discusses the source of the monitoring data and the approach used to effectively evaluate exposure data at a facility; Section 4 presents and evaluates the results of the analysis; and Section 5 lists references used to create this analysis.

2. EXPOSURE SETTING

The setting in which NPB is applied varies considerably depending on the size of the operation and the type of application. Adhesives are typically applied in either an open-top workbench spray area with side panels and some minor local ventilation, or in an open room with no mist containment (i.e., supplemental ventilation systems are assumed not to be present).

In general, the use of protective equipment during application of NPB is limited to safety glasses, aprons and caps. These items improve safety and limit potential dermal exposures (i.e., adhesive on worker's clothing or hair), but do not significantly reduce the amount of compound that may be inhaled. This exposure analysis focuses only on the effects of long-term inhalation of NPB and does not consider personal protective equipment, which can reduce exposure.

3. APPROACH

Monitoring Data

Monitoring is sometimes performed by facilities to determine if, and to what extent, a worker is exposed. When available, monitoring data give the best indication of the potential for exposure to workers. It is important to note, however, that the data reflect the workplace conditions in which the monitoring occurred and are not representative of conditions at all facilities.

Monitoring data for NPB exposure were available from three adhesive application facilities. These

facilities are the STN Cushion Company in Thomasville, NC; Custom Products, Inc., in Morrisville, NC; and Marx Industries in Sawmills, NC. The monitoring data include both exposure data obtained in the immediate vicinity of the actual spray application and in the entire room where NPB-containing adhesives are employed. Table 1 summarizes these observations.

TABLE 1. ADHESIVE EXPOSURE MONITORING DATA FOR NPB

Chemical	Monitoring Type	Chemical Concentration (ppm)		Monitoring Details
		Mean	Range	
STN Cushion Company, Thomasville, NC (November 2000)				
NPB	**Worker Monitoring/ Sampling**	**70.2**	**41.3-143**	**Exposure monitoring of fabrication sprayers; full shift (9 samples)**
NPB	**Area Air Sampling**	**--**	**7.2**	**Area air sample taken in fabrication room (1 sample).**
Custom Products, Inc., Morrisville, NC (November 2000)				
NPB	**Worker Monitoring/ Sampling**	**31.6**	**5.4-58**	**Exposure monitoring of covers sprayers; full shift (11 samples).**
NPB	**Area Air Sampling**	**--**	**1.1-1.9**	**Area air samples taken in sewing area (5 samples).**
Marx Industries, Inc., Sawmills, NC (November 1999)				
NPB	**Worker Monitoring/ Sampling**	**116**	**57.7-254**	**Exposure monitoring of all sprayers; full shift (12 samples)**
NPB	**Area Air Sampling**	**--**	**5.3-8.7**	**Area air samples (2 samples).**

As the table indicates, the monitoring values range from 5.4 ppm to 254 ppm. The range is a result of variations in both the amount of adhesive applied and the ventilation conditions. To better understand the potential level of occupational exposures for these varying conditions, a risk screening exposure assessment was performed. The risk screen models a hypothetical adhesive application facility and utilizes a box model to estimate concentrations of NPB that might be present in the air of the facility. The risk screen used a model because site-specific data are not available for the majority of facilities currently operating in the U.S. Workplace Air Concentrations The risk screening exposure assessment was conducted with the objective of determining potential occupational exposure concentrations to NPB for a variety of scenarios. The following four emissions scenarios were considered in this analysis. These scenarios are presented in Table 2.

C. Emissions from a facility with average ventilation and average adhesive use (S1);
D. Emissions from a facility with average ventilation and high adhesive use (S2);
E. Emissions from a facility with poor ventilation and average adhesive use (S3); and
F. Emissions from a facility with poor ventilation and high adhesive use (S4).

TABLE 2. SCENARIOS EVALUATED FOR NPB EIGHT-HOUR EXPOSURE CONCENTRATION ANALYSIS

Ventilation	Average adhesive use	High adhesive use
Average	**Scenario 1 (S1)**	**Scenario 2 (S2)**
Poor	**Scenario 3 (S3)**	**Scenario 4 (S4)**

A. Average Ventilation and Average Adhesive Use Facility (S1)

The general characteristics used in the modeling of the average ventilation and average adhesive use facility for the bonding of furniture and mattresses are:

- Average size facility: 65.7 meters x 65.7 meters;
- Average height of the facility: 7 meters;
- Typical lot size of 100 x 100 meters (~2.5 acres);
- Urban setting;
- Average-use adhesive mass emissions rate: 74 grams/minute;
- Facility operates 2000 hours per year (40 hr/week, 50 weeks/year);
- Average breathing height: 1.8 meters; and
- Air flow rate of 807 m^3/minute.

B. Average Ventilation and High Adhesive Use Facility (S2)

The general characteristics used in the modeling of the average ventilation and high adhesive use facility for the bonding of furniture and mattresses are:

- Same as S1 except for the adhesive use; and
- High-use adhesive mass emissions rate: 739 grams/minute.

C. Poor Ventilation and Average Adhesive Use Facility (S3)

The general characteristics used in the modeling of the poor ventilation and average adhesive use facility for the bonding of furniture and mattresses are:

- Three-story (30 feet) house, with a footprint of 25 feet x 40 feet;
- Urban setting;
- Average-use adhesive mass emission rate: 74 g/minute;
- Facility operates 2000 hours per year (40 hour/week, 50 weeks/year);
- Average breathing height of 1.8 meters; and
- Air flow rate of 192 m^3/minute.

D. Poor Ventilation and High Adhesive Use Facility (S4)

The general characteristics used in the modeling of the poor ventilation and high adhesive use facility for the bonding of furniture and mattresses are:

- Same as S3 except for adhesive application rate; and

• High-use adhesive mass emission rate: 739 g/minute.

Scenario 4, although not representative of most facilities, is expected to yield the highest exposure concentrations. These concentrations are useful for assessing the high-end exposure risk. Comparing Scenarios 1 and 2 and Scenarios 3 and 4 will show how the quantity of adhesive used effects exposure. Comparing Scenarios 4 and 2 will show how ventilation effects exposure. Comparing Scenarios 4 and 1 will show the high and low range of inhalation exposures and risks associated with variations in adhesive use and facility parameters.

Modeling Approach

The exposure point concentration for occupational inhalation exposure is determined by calculating the workplace air chemical concentration. The indoor air concentration for NPB was estimated using the following equation (EPA 1991):

Where:
$$C_a = \frac{Y_v x 1000 \frac{mg}{g}}{ATxk} x \frac{24.44}{MW}$$

C_a = Concentration of the chemical in air (ppm)
Y_v = Mass emission rate of volatile compound released (g/s)
AT = Air flow rate (m^3/s)
k = dimensionless room ventilation mixing coefficient (assumed as 0.5, EPA 1991)
MW = molecular weight (123.01 g/mole for NPB)

Note that 24.44 is a factor used to convert from mg/m^3 to ppm.

This box model approach has been widely used for many years to estimate probable exposures of workers to hazardous airborne materials, and has been described in detail by the National Institute for Occupational Safety and Health (NIOSH 1999).

The mixing factor or turnover rate, k, accounts for the slow and incomplete mixing of ventilation air with room air (i.e., the number of times one volume of air in the room is replaced over a period of time-typically one hour) and can be used to calculate an air flow rate if the size of the room is known. A value of 1 would represent complete mixing throughout the room and a very small value of k would approach the direct inhalation of the aerosolized NPB. Note that this model assumes that the entire area around the actual emissive source (i.e., around the sprayer) contains the same NPB concentration.

The model implicitly assumes that chemicals are completely volatilized into the air. The assumption is appropriate for NPB application given the volatility of NPB and the method of application (spray gun). Other model assumptions include:

- Incoming air is contaminant free;
- Volume of air in the room is exchanged at a constant rate (steady-state conditions); and
- Worker is continuously exposed to the same steady-state concentration of NPB during the 8-hour work day.

Model Inputs

Eight adhesive application facilities provided both general ventilation and room-size information (EPA 2001). Based on these data, an average airflow rate (AT) of 807 m^3/min was determined. However, a number of facilities are known to have no mechanical ventilation, and for these poor ventilation facilities an air turnover rate, k, of 0.5 hr^{-1}(ACGIH 1999) was used. Using the turnover rate of 0.5 hr^{-1} and an average room size of 1,440 m^2 (EPA 2001), an airflow rate of 192 m^3/min was determined to reflect facilities with poor ventilation.

The mass emission rate was calculated based on the average yearly adhesive-use rate for the surveyed facilities (EPA 2001). These data are log-normally-distributed. Following log-transformation, the average and 90th percentile values were taken as the average and high adhesive use rates. The average adhesive use rate for NPB is 2,874 gal/yr. and the high adhesive use rate is 28,736 gal/yr. The use rates were then converted to mass emission rates using the specific gravity of NPB (1.353), and assuming a 2000-hour work year.

4. RESULTS

The results of the analysis are outlined in Table 3. The exposure concentration from each of the scenarios modeled exceeds the recommended 8-hour AEL of 25 ppm. The S4 exposure concentration represents an upper range for the high-end exposure.

TABLE 3. EIGHT-HOUR EXPOSURE CONCENTRATION (ppm) TO NPB

	Average adhesive use	**High adhesive use**
Average Ventilation	60.3 (S1)	603 (S2)
Poor Ventilation	253 (S3)	2,533 (S4)

The modeling and monitoring results suggest that in the absence of supplemental ventilation systems (i.e. facilities with average or poor ventilation), workers could be exposed to nPB at levels significantly higher than the AEL. However, it should be noted that the NIOSH data from the Custom Products HHE Report (2000) indicate that installation of additional ventilation systems can reduce worker exposure to levels below the recommended AEL. Specifically, mean 8-hour TWA employee exposure at Custom Products was reduced from 169 ppm to 19 ppm after installation of local exhaust systems and spray booths (NPB Risk Screen section 5) .

Further investigation is warranted into the ventilation rates at the adhesive application facilities where data were collected, as well as actual NPB usage rates, and the degree to which workers are exposed based on their location throughout the day. Since this analysis assumes that the same concentration of NPB exists around the perimeter of the emission source, it may be necessary to refine the box model inputs as additional information regarding workers' activity levels in different zones/rooms throughout the workday becomes available.

Of the three facilities previously mentioned that use NPB as a spray adhesive, STN Cushion Company and Marx Industries, Inc. (both of which have insufficient ventilation at their facilities) have exposure

concentrations that are most comparable with the estimated values of S3. After installation of spray booths and local exhaust, employees at Custom Products, Inc., had exposure levels lower than the estimated value for S1.

5. REFERENCES

ACGIH, 1999. American Conference of Governmental Industrial Hygienists Industrial Ventilation: A Manual of Recommended Practice, 23rd edition, July 1999.

Reh, C., NIOSH, to M. Kiser, Marx Industries, Inc. February 2000. Letter containing data and conclusions for a November 16th, 1999 NPB exposure assessment conducted at Marx Industries, Inc., located in Sawmills, NC.

Reh, C., NIOSH, to S. Patch, Custom Products, Inc. December 2000. Letter containing data and conclusions for a November 16th, 2000 NPB exposure assessment conducted at Custom Products, Inc., located in Morrisville, NC.

Reh, C., NIOSH, to S. Cothran, STN Cushion Company, March 7, 2001. Letter containing data and conclusions for a November 14, 2000 NPB exposure assessment conducted at STN Cushion Company, located in Thomasville, NC.

U.S. EPA. 1991. Building Air Quality, Revised, EPA-402/F-91-102, EPA/Office of Indoor Air, December 1991.

U.S. EPA. 2001. Chapter 4. Exposure Assessment, Adhesive Technology Partnership, EPA Toxic Office, Design for Env1241.